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Training Ammunition for Force XXI

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Tank gunnery training in M1A1 and M1A2 units is currently accomplished with only two kinds of main gun training ammunition; M865 Target Practice, Cone Stabilized, Discarding Sabot-Tracer (TPCSDS-T) and M831 High Explosive, Antitank-Target Practice-Tracer (HEAT-TP-T).[1] Until recently, this has been adequate, only because Sabot and HEAT were the only service rounds available. This situation has already changed and will continue to change for the foreseeable future. Changes in the threats faced by the Armor Force, the development of new doctrine, and the introduction of new 120mm round types means that tank gunnery tables that include only M865 training sabot rounds and M831 training HEAT rounds should not be considered adequate.

While enemy tanks have never been the only threat that U.S. tanks have faced, our doctrine has emphasized them as the predominant one. This emphasis resulted from our preoccupation with a Soviet tank threat in Europe and our historical perspective, stretching back to the Second World War, of how to fight battles in a European Theater of Operations. However, the collapse of the Soviet Union has nearly eliminated any threat of a large-scale, tank-led invasion of Western Europe. While the number of tanks in the world has not really diminished, the *raison d'être* for the U.S. Army to maintain a large force of main battle tanks armed with *only* armor defeating main gun rounds has evaporated. Technological changes are also causing readjustments in assessments of threats to U.S. tanks. The introduction, some years back, of the long-range antitank missile and the antitank helicopter have placed new threats on the battlefield that a tank unit must be prepared to meet and defend against. Neither sabot nor traditional HEAT ammunition is particularly effective against these threats. Newer, more sophisticated smart tank munitions will also change the way our tanks are organized and equipped to fight. Enemy smart munitions - whether fired from a stealthy, high mobility platform, a mortar 5 kilometers away, or by a guerrilla from a second story window - will demand an agility of response that a tank equipped with only HEAT and sabot cannot provide.

In addition to the changes in the threat we face, and partially as a result of those changes, the Armor Force is reassessing its doctrine to take advantage of new technological capabilities. Desert Storm showed us the enticing possibilities available when you can outsee and outshoot your opponent. This capability is the direct result of the range advantage provided by our tanks, ammunition, and training. In addition, information technologies are driving the change towards a Force XXI doctrine. For the Armor Force, this new doctrine will extend battlespace in range and dimension. In other words, the tank of Force XXI must be able to see and shoot at extended range, to shoot at targets in the air, and to shoot at dug-in targets and those behind shelter in protected positions. The Force XXI tanker must also do this at a greatly elevated operational tempo. Target engagement decisions must be made instantaneously, and first shots must count. Anything less will bring defeat in the coming age of electronic decision-making and autonomous, guided munitions.

Finally, the basic load of tomorrow's tank will be very different than that carried today. In fact, the first round of ammunition for the Force XXI Armored Fleet, the M830A1 (MPAT) High Explosive Antitank-Multi-Purpose-Tracer (HEAT-MP-T), has already been fielded. The M830A1 is highly effective against armored vehicles, bunkers, and other ground targets. Importantly, it also provides American tankers with the world's first tank round with an effective antihelicopter capability, allowing American tankers to extend their battlespace into the third dimension. Other advanced tank rounds are currently being developed. The Smart, Target Activated, Fire and Forget (STAFF) round, currently in development, will provide us with an autonomously guided main gun round that flies over its target and fires down, denying our foes, for the first time, the protection afforded by digging in. Finally, the

fires down, denying our foes, for the first time, the protection afforded by digging in. Finally, the M829A3 Armor Piercing, Fin Stabilized, Discarding Sabot (APFSDS) kinetic energy round will provide unprecedented penetration capability at extended ranges.

New doctrine, new capabilities of the tank, and new ammunition will only go so far. To make the Armor Force as effective as possible, the quality of the tanker must remain high. The key that produces high quality tankers is, of course, high quality training. For the individual tank crew, the epitome of high quality training is realistic gunnery that stresses and improves the men and machines that make the Armor Force. For gunnery to be realistic, scenarios must replicate, to the extent safely possible, scenarios dictated by our doctrine and the threat. One of the issues that must be addressed for realistic training in the future is training ammunition. For the M1A1 and M1A2, our current inventory of training ammunition is ill equipped to address the training needs of the Force XXI tanker. There is currently no training round for the fielded M830A1. No training round is planned for STAFF, so gunnery tables will not include some of the unique features that will distinguish STAFF engagements. Finally, while we have a good KE training round in the M865, long-range engagements are just not in its repertoire. This deficiency in realistic training ammunition for tomorrow's tankers must be addressed soon with the development of a new generation of training ammunition and the ranges to support it.

Training Round Limitations

Training ammunition has unique limiting requirements. These limitations are driven by three competing factors. First, the ammunition must have a short maximum range. Second, within the limits of the maximum range, it must be as realistic as possible. Finally, and the 'Catch 22' in designing training ammunition, is that it must be relatively inexpensive so that enough may be procured to train the force.

A modern KE round will fly over 40 kilometers if fired at maximum elevation from level ground. The long range results from the desire to maximize muzzle velocity and minimize the aerodynamic drag on the round so that its striking velocity maximizes target penetration. At most, if not all, training areas, a 40 kilometer range will cause a round to overfly the impact area. Therefore, the range of training ammunition must be limited. In most cases, a range limitation of 8 kilometers is imposed on training ammunition. In other words, a round of training ammunition must hit the ground within 8 kilometers, 100 percent of the time, even if fired at maximum elevation. With current training ammunition, this range constraint is achieved by making projectiles with high-drag shapes. The M865, for example, uses a high-drag cone for stabilization, instead of the low-drag fins that are used on service KE. This allows the M865 to be launched with a high muzzle velocity. Its high drag slows it down rapidly; it loses more than 30 meters/second of velocity for every 100 meters traveled. Unfortunately, high-drag projectiles tend to lose accuracy as they lose velocity. Thus, it is difficult to turn high-drag projectiles into long range training rounds.

While range limitation is a primary requirement, there are other safety-related constraints on training ammunition design. Combined Arms, Live Fire Exercises (CALFEX) and platoon-level tank tables place several firing platforms on the training range at the same time. This creates obvious opportunities for fratricide. The M865, even with only a steel core, can damage an Abrams, and possibly hurt the crew, if the round strikes the tank's most likely impact point, the sides or rear, at close range. It will penetrate almost every point on a Bradley, likely resulting in the destruction of the vehicle and death or serious injury to the crew. Ideal training ammunition would, therefore, be nonpenetrating to prevent such tragedies. Also, most training ranges are not equipped to handle explosive rounds. Their destructiveness would destroy targets and target devices. The inevitable duds would leave explosives lying around in areas that must remain accessible. This makes development of training ammunition difficult for rounds that use explosive effects or do not have to strike their targets (STAFF and M830A1) to be effective. Finally, ricochets of the round or its fragments create a safety hazard that the ammunition developer must keep in mind.

For maximum training value, training ammunition must appear to replicate the performance of service ammunition. This requirement often competes with the safety requirements discussed above. For example, development of a training round for the M830A1 that could be fired in a ground-to-air training scenario will be difficult. Even assuming that a 'hovering helicopter' target could be effectively placed on a training range, simulating the proximity engagement of the M830A1 against this target would be difficult without some sort of explosive round.

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In addition to simulating the target effects of the service ammunition, training ammunition should have the look, feel, and handling of the corresponding service ammunition, so that the loader gets the most realistic training experience. If a round of service ammunition weighs almost 50 pounds and is over 40 inches long, the loader will get a false sense of handling ease if the training round only weighs 40 pounds and is less than 35 inches long.

Ideally, the ballistics of the training ammunition will also be the same as the service ammunition. This allows the same ammunition subdesignation (AMMO SUBDES) to be used. Again though, safety constraints, primarily the range restriction, make this difficult to achieve. As a case in point, the M865's ballistics are radically different than those of any of the M829 family of service KE.

As a final requirement, training ammunition must be inexpensive. A tank is allocated 78 M865s and 22 M831s for annual gunnery training. At approximately $646 for M865 and $697 for M831, the annual main gun ammunition costs for a battalion are already nearly $4,000,000. In these times of tight budgets, expensive training ammunition could cause a reduction in the number of rounds that each tank crew gets to fire. That could be a worse detriment to training than having training ammunition ill-suited to current service ammunition and doctrine.

Training Round Concepts

The first MPAT training round concept attempts to simulate an M830A1, in appearance only, by the application of a visual modification (VISMOD) to the existing M865 KE training cartridge. This is accomplished by using the entire M865 and attaching one of two plastic nose cap designs. Option 1 is a simple nose cap design that attaches to, and covers only the spike of the M865. Option 2 is a larger design that, like the first option, attaches to the spike of the M865, but extends to the sabot, making the cartridge a more realistic portrayal of an M830A1. Both design configurations retain the M865's trajectory since the nose cap adapter separates from the projectile when fired.

The VISMOD concept was ultimately rejected for a variety of reasons. Most importantly, it did not meet the look, touch, and feel operational requirements. The overall appearance with either nose cap is marginal at best. The VISMOD concept also failed the operational requirement that the MPAT trainer cartridge weight be within 4 lbs. of the M830A1. In fact, the VISMOD trainer is 12 lbs. lighter than the service MPAT round, and the weight distribution is significantly different than the M830A1. With VISMOD attached, the cartridge is also 3 inches shorter than the M830A1. All the physical differences between the M830A1 and the VISMOD cartridge mean that the loader cannot achieve an accurate training experience with this concept.

The second concept, a full developmental MPAT Trainer program (dubbed the XM1002 MPAT Trainer), meets the operational requirements and was selected to become the future replacement to the M831 HEAT training round. Unlike the VISMOD proposal, the XM1002 will pass the `look, touch and feel' test. Its exterior configuration and dimensions replicate the M830A1 exactly, to include a movable Air/ Ground fuse cap. The cartridge weight is just 2 lbs. lighter than the service round, and importantly, the weight distribution of the training cartridge is right on the mark. In an effort to reduce the expense and lead time associated with new developmental programs, the XM1002 will use common M830A1 components, specifically, the propulsion system and the sabot. A significant reduction in system cost is also expected by reutilizing propellant from demilitarized M829s.

Planning for future performance improvements to the MPAT Trainer should also begin now. As mentioned above, the current MPAT Trainer concept still does not include a ground-air mode. Future improvements to the round and training ranges must enable tankers to engage air targets. Current and emerging technology should enable ammunition developers to achieve this significant performance improvement cheaply and in the near term. Most importantly, this added capability would provide tank crews a more accurate training experience.

Long Range KE Trainer. See, Hit, Kill. In Desert Storm, U.S. tankers were engaging targets at the limits of the ability of the tank's sights and well beyond what they were used to firing in training. Long range

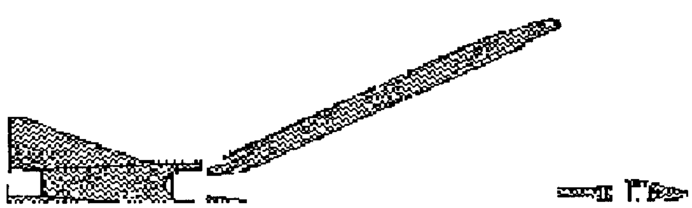
of the ability of the tank's sights and well beyond what they were used to firing in training. Long range gunnery will continue to be the norm in combat. Force XXI doctrine stresses the extension of battlespace. Newer, higher fidelity target acquisition technologies are being fielded with the M1A2 and improvements in gun, ammunition, and fire control are making even longer range engagements possible. This means that there is a growing need to pursue a tank training ammunition development program that will allow soldiers to "train the way they are expected to fight" in the future. Unfortunately, the current M865 KE Trainer will not accommodate long range gunnery requirements. Its probability of hit (Ph) at ranges beyond 2 kilometers is just not acceptable.

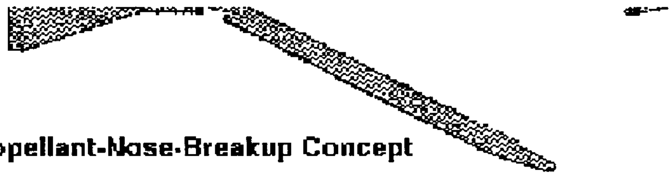
Developing a long range gunnery training capability is not a simple matter. Nearly all multi-purpose range complexes (MPRC) are limited by an 8 kilometer range fan. Although some can extend another 2-4 kilometers, only the National Training Center (NTC) can currently accommodate the needs of long range gunnery training. A major MPRC upgrade directed at expanding the range limits of MPRCs throughout the U.S. Army would be prohibitively expensive, even if possible. However, there are MPRCs that cannot be expanded beyond their current range limitations, so they would be left out of the upgrade. Another option would limit long range tank gunnery training to a unit's annual NTC rotation. Although possible, it would probably provide only familiarization, rather than adequate long-range gunnery training, plus, it would leave the OCONUS units unable to even familiarize at the longer ranges. The UCOFT can fill some of the void, but can never fully satisfy the requirement. The best way to fulfill a long range gunnery training requirement is to develop a long range KE trainer that will perform to specified requirements, yet be safe to fire at all MPRCs as they currently exist.

Anticipating the need for extended range training ammunition, tank ammunition developers are currently examining the possibilities for future long range training round candidates. A simple improvement to the current M865 KE trainer may seem to be the obvious solution. In fact, the M866 Long Range KE Trainer was produced several years ago and is an extremely accurate round. It combines the penetrator of an M865 with fins replacing the M865's tail cone. The max range of the M866 is typical of finned KE rounds, however, and its use would be restricted to the tank gunnery range at the NTC.

Another concept is known as the M865E2. The M865E2 was born through the M829 reclamation program, the goal of which was to convert M829 APFSDS-T cartridges (Tactical) to new TPFSDS-T cartridges (Training). The M829's depleted uranium (DU) core was replaced, but most other M829 components are reused. As an added benefit, the M865E2 is much closer to the look, touch, and feel of service KE than is standard M865. A version of the M865E2 has been designed for long range firing and is still in development. Like the M866 however, the M865E2 (Interim Long Range Training Cartridge Version) will probably not be range-limited to 8 kilometers.

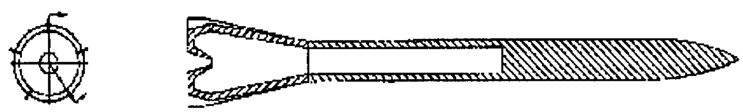
This brings us back to the basic question: How can we design a 120mm KE trainer cartridge that performs at extended range, but falls to earth within 8 kilometers? Currently, the only choice seems to be to design-in a 'braking' system. A number of concepts with this feature have been suggested and examined. The most promising of these are being considered as possible alternatives to the M865E2 and are described below. As always, safety remains the number one design constraint, and the reliability of the `braking' system is the key safety factor for all the concepts.





Propellant-Nose-Breakup Concept

In the Propellant-Nose-Breakup[2] concept, the body segment of the projectile rod is split down the center. The bottom of the split rod penetrator is held together by a solid metal base and fin. The tip of the penetrator is held together by a heat sensitive nose cap. The idea takes advantage of aerodynamic heating of the nose cone during the projectile flight. At a specific range, the nose cone gets hot enough to cause propellant imbedded in the nose cap to ignite. Once ignited, the shear pins that hold the nose cap together fail; the projectile breaks up; and the pieces tumble quickly to the earth. Currently, this concept is the most mature of the range-limited, long-range training round concepts and was demonstrated some years ago. Reliability remains a concern, however. Two problems occur if the nose propellant fails to ignite. First, the penetrator will not break up and the round could overfly the impact area. Second, the nose cap will contain an unburned propellant and would probably require handling by EOD personnel.

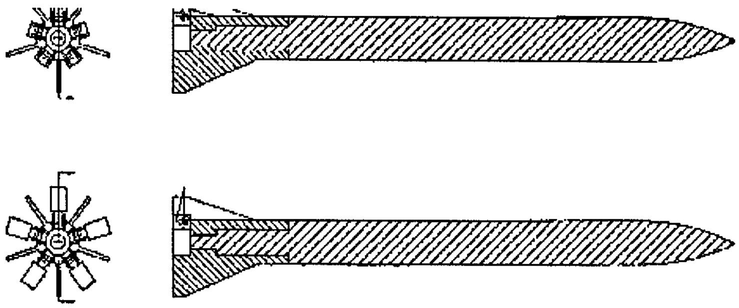


Boosted-High-Drag-Projectile Concept

The Boosted-High-Drag-Projectile[3] concept is a projectile with an aluminum body and a steel nose. Aerodynamic stability and high drag is achieved with a straked cone,[4] rather than fins. Extended range is achieved by the using a small, solid propellant rocket engine to offset the high drag during the first few kilometers of flight. This feature is invisible to the tank crew, and the round is launched normally. Following the launch, the rocket engine ignites for approximately 2.1 seconds and burns to 3 kilometers. At 3 kilometers range, the rocket engine burns out and the high drag cone slows down the projectile enough to cause it to hit the ground within 8 kilometers. Essentially, this is a fail-safe cartridge. If the rocket engine fails, the round's range is limited by the tail cone in the same way as an M865. Unfortunately, this training round could also contain unburned propellant material (the rocket motor). A round whose motor failed would have to be handled by EOD personnel.

The Ablative-Nose-Projectile[5] concept was validated at the same time as the Propellant-Nose-Breakup concept. This concept integrates a standard training projectile body, a 5- or 6-bladed fin and a nose cone of ablative material.[6] Aerodynamic heating generated during the flight of the round causes the nose cone to ablate away during flight, thus changing its shape and aerodynamic characteristics. At some design range, the nose cone is ablated to a level that its changed aerodynamics destabilize the projectile. As stability is lost and drag increases, the round starts tumbling and falls to earth. Performance reliability is less of a concern, but is still a consideration. The round must function properly. If not, the projectile will travel well beyond the 8 kilometer range limitation.

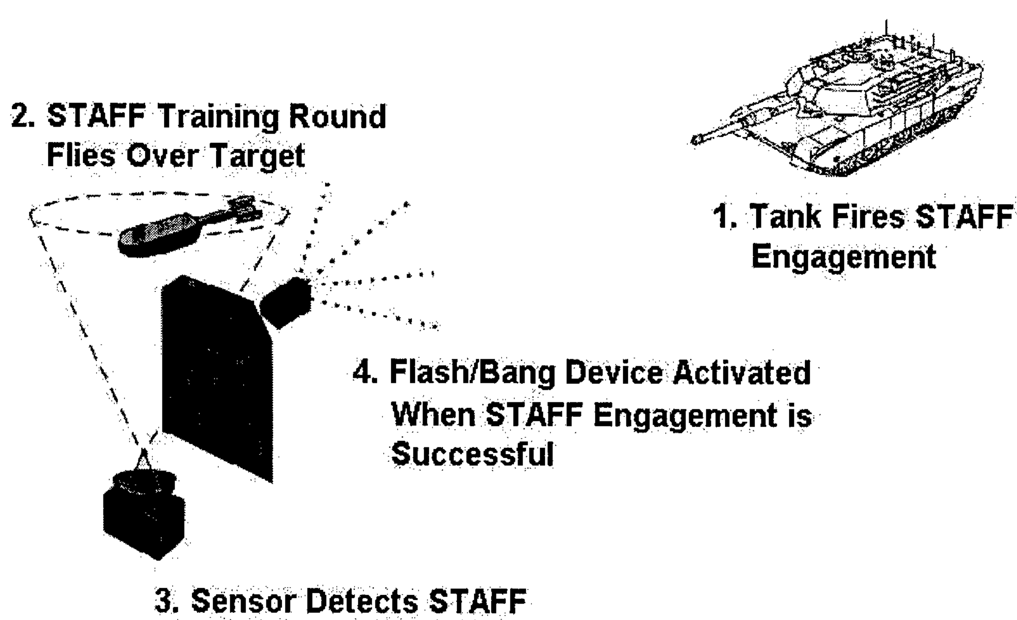
The Ablative-Fin-Projectile concept[7] is similar to the Ablative-Nose-Projectile concept. It also integrates a standard training projectile body, spike nose, and a 5- or 6-bladed fin. Instead of the nose being made of ablative material, one or more of the fin blades is made of this material. Again, the aerodynamic heating generated during flight causes ablation of material, but this time at the fin. The fins retain their stabilizing capability to the maximum desired engagement range. Beyond this range though, one or more fin blades is ablated enough to cause the projectile to lose stability and tumble to the earth within the 8 kilometer range limitation.



Low Drag/High Drag Fin Concept (Drogue Flap)

The Low Drag/High Drag Fin Concept (Drogue Flap)[8] integrates a standard training projectile body, spike nose, 5-bladed fin, and a 'braking' system. The braking system is made up of five sets of pin holders, pins, and drag flaps. They are attached to and hidden at the base of the projectile, but forward of the fin. When the drag flaps deploy, they provide a high level of aerodynamic drag in a manner similar to the air brakes on aircraft. With the flaps folded, the round is nearly as aerodynamic as service sabot, so it can have the same level of accuracy. The drag flaps are designed to deploy at a specified range. This range is set so that it is beyond the maximum engagement range of the training exercise, but short enough to give the flaps time to drag the projectile down inside the 8 kilometer range limitation. Performance reliability is a concern in any concept that requires the round to actively do something, and the Drogue Flap concept is no exception. If the 'brakes' do not function properly, the round will travel beyond the 8 kilometer range limitation.

STAFF Trainer. Development of a STAFF training round is not being considered at this point. Instead, the plan is to train STAFF engagements only in a simulation environment. This decision is based primarily on the perceived cost of a STAFF training round, but it could have an adverse impact on the training of tank crews. The STAFF is easily the most radical of the new rounds being fully developed for the Force XXI tank fleet. It can be used to engage very long range targets, targets in defilade, maneuvering targets, and flying targets. Since there will probably only be a few STAFFs in the basic load, deciding which round to use becomes a critical skill for the tank commander. The gunner and loader must also be well trained in its use. With only a few of these high cost, high payoff rounds, the tank crew must insure that they are not wasted because of inadequate training. The best and most realistic training for STAFF can only occur on a gunnery range.



There are ways to get around the potentially high cost of a STAFF training round. One method is to avoid making the training round a non-explosive copy of a real STAFF. Instead, by tying the training range and the round together, the overall cost of the round can be greatly reduced. To minimize the cost of the training round itself, the flight body of the round could be reduced to an inert slug. Folding fins are required on the actual STAFF in order to rotate the explosively formed penetrator (EFP) to its correct orientation in relation to the target. A slug round does not have an EFP, hence does not need the complex and costly control mechanisms and folding fins of the real STAFF. Inexpensive, static fins, similar to those on the M831, would probably suffice for flight stability of the slug. In terms of training, this is okay since the tank crew only sees the actual STAFF from the adapter forward and the tail and fins of a real STAFF are hidden from the crew in the cartridge case. The training STAFF would not need to carry the expensive electronics of the real round either. On a gunnery range roles can be reversed and the target can sense the STAFF, instead of vice versa. A directional sensing device, such as a radar or sky screen, could be placed in a protected position just behind the target. It is possible to make such a device `look' into the space above the target and sense if a STAFF training round flies over the target and through the basket from which an EFP could be successfully launched. When a successful engagement is sensed at the target, a flash/bang device (such as a Hoffman device) would be activated at the target.[9] This would simulate the launching of an EFP so the tank crew could sense the engagement and be scored accordingly.

This training round concept has a number of advantages. First is cost. A slug round, as described above, should cost approximately the same as current training rounds. Some additional cost for the sensing and flash/bang devices will be incurred, but this should be small over the life of the device. This kind of training round and its associated target equipment could also be used on all current tank ranges that allow main gun firing. Finally, and most importantly, use of this training scheme would simulate a STAFF engagement to the tank crew. The tank commander would issue a fire command and call for STAFF. The gunner would index STAFF, identify the target, and announce the range. The loader would set the range switch (could be a dummy) and load the round. The gunner would fire the round. The round now only has to fly over the target. The round is sensed as it overflies the target, and if it flies through the correct basket, a flash/bang is activated and detected by the crew.

Conclusion

New doctrine and technology is changing the way the Armor Force will fight its future battles; therefore, the need for new training ammunition is real. New service ammunition has been, or will be, introduced into the Army that has no counterpart in the training world. If we are to remain true to the credo that we train the way we fight, the Armor Force's training tools need adjustment. The best tank, ammunition, and war fighting doctrine in the world must continue to be complemented by the world's best training, and that requires new training ammunition.[10]

Notes

[1]The M831 is currently being replaced by the M831A1. For the tank crew, the difference is invisible.

[2]Armaments Research, Development and Engineer Center (ARDEC) concept. The Propellant-Nose-Breakup Concept is a variant of the 105mm XM797.

[3]The Boosted-High-Drag-Projectile Concept was developed within the Weapons Technology Directorate of the Army Research Laboratory.

[4]Aerodynamic strakes are raised bands of material that extend along a surface. In this case, think of them as long, very low fins that extend the length of the tail cone.

[5]The Ablative-Nose-Projectile Concept is the original 105mm XM797 concept that was developed by ARDEC in the late 1970s and tested in the early 1980s.

[6]Ablation is a process of burning away a surface. Ablative materials are formulated to absorb heat energy by controlled burning away of the surface material.

[7]ARDEC concept.

[8]The Low Drag/High Drag Fin Concept (Drogue Flap) was developed within the Weapons Technology Directorate of the Army Research Laboratory.

[9]The authors would like to thank Mr. Mark Frank of ARDEC for some simplifying suggestions to this concept.

[10]The authors would like to thank the people who read drafts of this article and made many helpful suggestions. In particular, Mr. Ed Fennell and Phil Donadio of ARDEC, Mr. Don Guziewicz and MAJ Dave Gallop of PM TMAS, and Mr. Al Pomey and SFC Robert Horner of the Armor Center.

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